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ON COMMUNICATION PROCESSES INVOLVING LEARNING AND RANDOM DURATION

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ABSTRACT

Previously we have shown that the fundamental problem of determining the utility of a communication channel in conveying information ~~may be~~ is viewed as a problem within the framework of multi-stage decision processes of stochastic type, and as such ~~may be~~ is treated by the theory of dynamic programming. ~~Furthermore~~ the relations between utility and capacity, in Shannon's sense, ~~have been~~ are indicated.

~~Following a brief resumé of the foregoing, we show how to~~ treatment of communication problems involving the use of a channel whose properties are not completely known, and those involving processes of random duration, are shown. ~~These are special cases of still more general problems in prediction theory~~.

~~Our aim is to show how quite~~ Treatments of general processes ~~can be treated~~ in a uniform fashion by the functional equation technique of dynamic programming, are discussed. ( )

SUMMARY

ON COMMUNICATION PROCESSES INVOLVING LEARNING AND RANDOM DURATION

by

Richard Bellman and Robert Kalaba

In two earlier papers, [2], [3], we have shown how several general classes of stochastic communication problems may be viewed as multi-stage decision processes of stochastic type, [1]. Our purpose here is to extend these considerations to more general and realistic communication situations involving (1) channels whose properties are only partially known; (2) communication processes of random length; (3) allocation of signal detection equipment.

Our discussion revolves around the determination of the 'utility' of a communication channel, where, naturally, the utility depends upon the use to which the channel is to be put. We conceive of a three-element communication system consisting of a source of signals, a communication channel, and an observer, and assume that the observer uses the received signals (in an optimal fashion) to aid in achieving some objective, in the course of a multi-stage process. The utility of the channel can then be measured by comparing the observer's performance against the performance of a hypothetical reference observer provided with an error-free channel, or against one provided with no channel at all.

The situations covered are quite broad in scope. Not only do our considerations apply to strictly technological communication problems, but also to general problems of experimental physics, in which nature

is the source, the experimenters are the channel, and the scientific corps is the observer. Also describable in this way are problems of forecasting (weather or economic conditions), etc.

We have shown previously how a variety of problems arising from this general framework can be formulated as problems involving functional equations of a novel type which can be solved analytically in some cases and in other cases by the use of computing machines. In particular, generalizing and extending results of Kelly, [4], we have indicated the connection between channel utility and channel capacity in the sense of Shannon.

In the present work, we consider the important case in which the channel has fixed, but not completely known, characteristics. In the course of the process, the observer not only makes decisions on the basis of knowledge possessed, in an effort to attain his goal, but also attempts to deduce the characteristics of the system from the events that have occurred (see Robbins, [5], for an interesting exposition of learning processes). Depending on how the term 'not completely known' is interpreted, we obtain a hierarchy of processes which can be treated by the functional equation technique of dynamic programming.

Next we consider processes, which in addition to possessing the previous features possess the complication of having random duration. Various radar detection processes are of this type.

The foregoing problems are in turn special cases of still more general problems arising in prediction theory. Here we encounter the additional difficulties of utilizing various types of channels, with different reliability characteristics and different costs. Finally,

extensions of these processes lead to problems involving limited storage of information, and delays in both processing information and evaluating the results of previous decisions.

Our aim throughout is to illustrate how quite general processes of the types described above can be treated in a uniform fashion by means of the theory of dynamic programming.

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